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THE COMPUTATION OF FERTILIZER MIXTURES FROM CONCENTRATED MATERIALS

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INTRODUCTION

The principal inorganic materials now used in the manufacture of fertilizers are acid phosphate, sodium nitrate, ammonium sulphate and various potash salts. All of these materials, which amount to 70 per cent of the total consumed in the fertilizer industry in this country, have the feature in common that they contain but one fertilizing element. A number of organic materials such as cottonseed meal, tankage, and fish scrap contain marketable quantities of two, or even all three, of the essential constituents of fertilizers; but it often happens that the value of one of the constituents so much exceeds that of the others that the latter are frequently disregarded. The calculation of the materials required in the manufacture of the great bulk of mixed fertilizers is therefore a comparatively simple matter.

Thus, for example, the quantity of a material, such as ammonium sulphate with 25 per cent ammonia, required in a ton (2,000 pounds) of a fertilizer mixture to contain, say, 8 per cent of ammonia is simply obtained by multiplying the latter percentage by 2,000 and dividing by the former percentage ($2,000 \times 8/25 = 640$). Or, in general, if a is the per cent of ammonia in the material, and A the desired percentage of ammonia in the complete fertilizer, then X (the quantity of material required) is given by the equation $X = \frac{2,000\ A}{a}$.

In the same way, the quantities Y and Z of the phosphoric acid and potash materials required in a complete fertilizer are given by the equations:

$$Y = 2,000\frac{B}{b} \quad \text{and} \quad Z = 2,000\frac{C}{c}$$

where B and C respectively are the percentages of phosphoric acid and potash desired in the fertilizer, and b and c the actual percentages in the materials used.

Having obtained X, Y, and Z, the quantity of filler (F) to be used in the mixed fertilizer is given by the equation $F = 2{,}000 - (X+Y+Z)$.

It is evident that the sum, $X+Y+Z$, can not exceed 2,000 pounds, making F a minus quantity; for, in such a case, though the desired relative proportions of the respective fertilizing elements could be maintained, the desired analysis formula[1] could not be obtained by using the particular materials available.

In Table 1[2] are given directly values of X, Y, and Z, with variations of A, B, or C, from one-half to 20 per cent; and of a, b, or c, from 1 to 50 per cent. Thus, to find the amount of a material (containing any particular per cent of fertilizer constituent given in the first column of figures) required for 2,000 pounds of fertilizer (containing a desired per cent of the same constituent given in the top line of figures), use the number of pounds of this material shown where the horizontal and vertical lines from the two percentages cross.

TABLE 1.—*Weights of single fertilizer constituent materials required for fertilizer formulae*

Per cent in material	Per cent desired																				
	½	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	1000	2000	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
2	500	1000	2000	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
3	333	667	1333	2000	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
4	250	500	1000	1500	2000	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
5	200	400	800	1200	1600	2000	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
6	167	333	667	1000	1333	1667	2000	----	----	----	----	----	----	----	----	----	----	----	----	----	----
7	143	286	571	857	1143	1429	1714	2000	----	----	----	----	----	----	----	----	----	----	----	----	----
8	125	250	500	750	1000	1250	1500	1750	2000	----	----	----	----	----	----	----	----	----	----	----	----
9	111	222	444	667	889	1111	1333	1556	1778	2000	----	----	----	----	----	----	----	----	----	----	----
10	100	200	400	600	800	1000	1200	1400	1600	1800	2000	----	----	----	----	----	----	----	----	----	----
11	91	182	364	545	727	909	1091	1273	1455	1636	1818	2000	----	----	----	----	----	----	----	----	----
12	83	167	333	500	667	833	1000	1167	1333	1500	1667	1833	2000	----	----	----	----	----	----	----	----
13	77	154	308	462	615	769	923	1077	1231	1385	1538	1692	1846	2000	----	----	----	----	----	----	----
14	71	143	286	429	571	714	857	1000	1143	1286	1429	1571	1714	1856	2000	----	----	----	----	----	----
15	67	133	267	400	533	667	800	933	1067	1200	1333	1467	1600	1733	1867	2000	----	----	----	----	----
16	62	125	250	375	500	625	750	875	1000	1125	1250	1375	1500	1625	1750	1875	2000	----	----	----	----
17	59	118	235	353	471	588	706	824	941	1059	1176	1294	1412	1529	1647	1765	1882	2000	----	----	----
18	55	111	222	333	444	556	667	778	889	1000	1111	1222	1333	1444	1556	1667	1778	1889	2000	----	----
19	52	105	211	316	421	526	632	737	842	947	1053	1158	1263	1368	1474	1579	1684	1789	1895	2000	----
20	50	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000
21	47	95	190	286	381	476	571	667	762	857	952	1048	1143	1238	1333	1429	1524	1619	1714	1810	1905
22	45	91	182	273	364	455	545	636	727	818	909	1000	1091	1182	1273	1364	1455	1545	1636	1727	1818
23	43	87	174	261	348	435	521	608	695	782	869	956	1043	1130	1217	1304	1391	1478	1564	1651	1738
24	41	83	167	250	333	417	500	583	667	750	833	917	1000	1083	1167	1250	1333	1417	1500	1583	1667
25	40	80	160	240	320	400	480	560	640	720	800	880	960	1040	1120	1200	1280	1360	1440	1520	1600
26	38	77	154	231	308	385	462	538	615	692	769	846	923	1000	1077	1154	1231	1308	1385	1462	1538
27	37	74	148	222	296	370	444	519	593	667	741	815	889	963	1037	1111	1185	1259	1333	1407	1481
28	35	71	143	214	286	357	429	500	571	643	714	786	857	929	1000	1071	1143	1214	1286	1357	1429
30	33	67	133	200	267	333	400	467	533	600	667	733	800	867	933	1000	1067	1133	1200	1267	1333
35	29	57	114	171	229	286	343	400	457	514	571	629	686	743	800	857	914	971	1029	1086	1143
40	25	50	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	850	900	950	1000
45	22	44	89	133	178	222	267	311	356	400	444	489	533	578	622	667	711	756	800	844	889
47	21	43	85	128	170	213	255	298	340	383	426	468	511	553	596	638	681	723	766	809	851
48	21	42	83	125	167	208	250	292	333	375	417	458	500	542	583	625	667	708	750	792	833
49	20	41	82	122	163	204	245	286	327	367	408	449	490	531	571	612	653	694	735	776	816
50	20	40	80	120	160	200	240	280	320	360	400	440	480	520	560	600	640	680	720	760	800

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[1] The following expressions, when occurring in this bulletin, are used to mean as follows:

"Fertilizer analysis formula," or simply "analysis formula," the formulated statement of the percentages of ammonia, phosphoric acid, and potash in a fertilizer. Thus 3-9-3 is the "analysis formula" of a ertilizer guaranteed to contain 3 per cent NH_3, 9 per cent P_2O_5, and 3 per cent K_2O.

"Fertilizer ratio," the formulated statement of the percentages of ammonia, phosphoric acid, and potash, in a fertilizer when expressed on the basis of the fertilizing elements alone.

"Fertilizer formula," or "formula," a statement of the ingredients and weights of each required to make a ton of a mixed fertilizer.

[2] Compiled from data given in Table 2, Bull. 221, p. 15, Va. Agr. Expt. Sta., with additions.

If it is desired to supply a fertilizer constituent, such as ammonia, from two or more single constituent materials, it is customary to decide arbitrarily beforehand on the percentage of the constituent in the fertilizer which shall be supplied by each material. The quantity of each material to be taken is then found directly in the usual way by reference to Table 1.

When one or more of the materials used in a fertilizer contains more than one fertilizer constituent, the calculation of the mixture can most conveniently be done by listing the data in tabular form, as illustrated in Table 2. Of the materials listed in the table for use in a 3–8–3 mixture, three contain ammonia. If it is decided that the sodium nitrate shall supply half of the ammonia (or 30 pounds per ton of fertilizer) and the cottonseed meal and tankage 15 pounds each, then the weights of these materials required to yield these quantities of ammonia are 162, 200, and 177 pounds, respectively. But 200 pounds of cottonseed meal also contain 5.6 pounds of P_2O_5 and 3.4 pounds of K_2O, while 177 pounds of tankage contain 8.8 pounds of P_2O_5. The remaining 145.6 pounds of P_2O_5 and 56.6 pounds of K_2O require, respectively, 910 pounds of acid phosphate and 283 pounds manure salt.

TABLE 2.—*Method of listing data for 3–8–3 fertilizer mixture*

Materials	Composition			Constituents required			Material required
	NH_3	P_2O_5	K_2O	NH_3	P_2O_5	KO_2	
	Per cent	*Per cent*	*Per cent*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Nitrate of soda	18.5			30.0			162
Cottonseed meal	7.5	2.8	1.7	15.0	5.6	3.4	200
Tankage	8.5	5.0		15.0	8.8		177
Acid phosphate		16.0			145.6		910
Manure salt			20.0			56.6	283
Total				60.0	160.0	60.0	1.732
Filler							268
							2,000

The general formula for the calculation of a fertilizer mixture of this kind may be expressed as follows:—

If a = Percentage of NH_3 in sodium nitrate
a' = Percentage of NH_3 in cottonseed meal
a'' = Percentage of NH_3 in tankage
b = Percentage of P_2O_5 in cottonseed meal
b' = Percentage of P_2O_5 in tankage
b'' = Percentage of P_2O_5 in acid phosphate
c = Percentage of K_2O in cottonseed meal
c' = Percentage of K_2O in manure salt

then for an $A–B–C$ fertilizer:

$$X\text{, sodium nitrate required} = 2{,}000\ \frac{A/2}{a}$$

$$X'\text{, cottonseed meal required} = 2{,}000\ \frac{A/4}{a'}$$

$$X''\text{, tankage required} = 2{,}000\ \frac{A/4}{a''}$$

$$Y\text{, acid phosphate required} = \frac{2{,}000\ B-(bX'+b'X'')}{b''}$$

$$Z\text{, manure salt required} = \frac{2{,}000\ C-cX'}{c'}.$$

When each of the three fertilizing elements of a mixed fertilizer is supplied by one or more simple constituent materials, with or without the addition of two or three constituent materials, considerable leeway is possible in the proportions of the like constituent materials which may be taken, and in such cases there is little or no advantage in the use of a general formula for the calculation of such mixtures.

As the number of materials, particularly single-constituent materials, available for a fertilizer mixture is reduced, the range of fertilizer analysis formulae which they are capable of making is also reduced, and the difficulty of the ordinary arithmetic method of calculating any given mixture may be greatly increased.

It is likely that in the future fewer materials will be used in mixed fertilizers, and that the concentration of these materials will be greater. This condition is to be expected from reasons to be discussed later. The object of the present bulletin is, therefore, to outline simple methods for determining the possible fertilizer ratios which may be made from concentrated fertilizer materials, and for calculating the quantities required for any given fertilizer analysis formula.

THE TRIANGULAR SYSTEM FOR FERTILIZER MIXTURES

From the trade standpoint the value of a complete fertilizer, in the present development of the fertilizer industry, is based entirely on the available ammonia, phosphoric acid, and potash present, and is independent of the number of materials in the mixture. Variations in the composition of mixed fertilizers may therefore be represented by use of a system of three coordinates corresponding to the three variables, ammonia, phosphoric acid, and potash. Such a system of coordinates is the triangular system[3] and the range of fertilizer ratios which can be made from fertilizer materials can be readily determined with the aid of triangular section paper as represented in Plate I.

The corners *A*, *B*, and *C* of the triangle represent 100 per cent of NH_3, P_2O_5, and K_2O, respectively. The distance from each corner of the triangle to the opposite side is divided into 100 equal parts. The sum of the distances along the respective perpendiculars, from any point within the triangle to the opposite sides, will always amount to 100 of these divisions. Each point within the triangle will therefore represent a definite mixture of all three constituents in such proportion as to total 100 per cent. Thus the point *E*, being 25, 50, and 25 divisions from the sides *BC*, *CA*, and *AB*, respectively, represents a mixture in which 25 per cent of the total fertilizing material is NH_3, 50 per cent is P_2O_5, and 25 per cent is K_2O. This point, therefore, represents a 25–50–25 fertilizer ratio, or any submultiple of this ratio, such as 4–8–4. Each side of the triangle represents varying mixtures of the two constituents represented by the adjacent corners but none of that of the opposite corner. Thus the side *AB* represents mixtures containing varying amounts of NH_3 and P_2O_5 but no K_2O; and the side *CA* varying amounts of K_2O and NH_3 but no P_2O_5. Any particular point on a side represents a definite mixture of the two constituents represented. The point *D* on the side *AB*, for example, being 40 divisions from *BC* and 60 divisions from *AC*, corresponds to a fertilizer mixture which contains 40 per cent of the total fertilizing elements as NH_3, 60 per cent as P_2O_5 and 0 per cent K_2O.

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[3] The triangular diagram has been used by Schreiner and Skinner (J. Am. Soc. Agron. Vol. 10, pp. 225–246, 1918) in their experimental fertilizer mixtures for studying the effect on plants of different ratios of the fertilizing elements, ammonia, phosphoric acid, and potash.

A material such as sodium nitrate, in which the NH_3 amounts to 100 per cent of the fertilizing elements present, will be represented on the triangle by the point *A*. Similarly, acid phosphate will correspond to the point *B*, and a potash salt to the point *C*. As the lines joining these three points coincide with the boundary lines of the triangle, it follows that submultiples of any fertilizer ratio whatever may be made by combinations of these three materials. The maximum fertilizer analysis formula possible for any given ratio is obtained by multiplying by the factor $\frac{2000}{X+Y+Z}$. Thus, if the sodium nitrate contains 18 per cent NH_3, the acid phosphate 16 per cent P_2O_5, and the potash salt 20 per cent K_2O; then, for a 4–8–4 mixture, $X=444$, $Y=1000$, $Z=400$, and $X+Y+Z=1844$. The maximum possible analysis formula, corresponding to the mixture 4–8–4, that can be made from these materials is, therefore, $\left[\frac{2000}{1844}(4\text{–}8\text{–}4)\right]$ or 4.34–8.68–4.34.

A material, for example a tankage containing, say, 8.5 per cent NH_3 and 5 per cent P_2O_5, would have 63 per cent of its fertilizing elements in the form of NH_3 and 37 per cent as P_2O_5, and would be represented in the triangle on the side *AB* by the point *F*. Submultiples of all ratios which fall within the triangle *FCB* can therefore be made from this material in combination with acid phosphate, and a potash salt, while those which fall outside this triangle, such as the analysis formula 5–2–3 corresponding to the ratio 50–20–30 represented by the point *G*, can not be made. *G*, however, falls within the triangle *FCA*, and, therefore, submultiples of the ratio 50–20–30 can be obtained by combinations of tankage and potash salt with a nitrogenous material.

If the ammonia in a fertilizer mixture is to be obtained from nitrate of soda, cottonseed meal, and tankage, in the proportions given in Table 2, then 2 of a total of 4 parts of NH_3 will be present in the mixture as nitrate, 1 as cottonseed meal, and 1 as tankage. But the quantities of the two last materials, which contain 1 part each of NH_3, also contain 0.96 part of P_2O_5 and 0.23 part of K_2O. The mixture of these three materials therefore contains 77 per cent of the fertilizer constituents as NH_3, 19 per cent as P_2O_5, and 4 per cent as K_2O, and may be represented in Plate I by the point *H*. Submultiples of all ratios which fall within the triangle *HBC* can be made by combinations of these three materials with acid phosphate and potash salt. The maximum fertilizer analysis formula that can be made of any of these ratios is obtained in the usual way by multiplying by the fraction $\frac{2000}{X+X'+X''+Y+Z}$.

FACTORS THAT INFLUENCE THE CONCENTRATION OF FERTILIZERS

The principal sources of each of the three essential constituents of fertilizers are saline or mineral deposits and industrial by-products. Phosphate rock is the principal source of phosphoric acid, but the latter also occurs in bones, fish scrap, and cottonseed meal. The potash comes from saline and mineral deposits, and industrial wastes such as cement-mill dust, tobacco stems, and sugar-beet liquors. The nitrogen is obtained from even more diverse sources such as the nitrate deposits of Chile and the waste products of many industries.

The percentages of nitrogen, phosphoric acid, and potash in almost all these raw materials are comparatively low. No nitrogen deposit or waste material contains more than 15 per cent of nitrogen. The Alsatian potash deposits may run as high as 20 per cent of potash, but there are no known deposits or materials in this country which contain more than 12 per cent of potash. Phosphoric acid occurs in fairly high concentration in phosphate rock, but in the process of manufacturing commercial acid phosphate the concentration is reduced to about 16 per cent.

Other materials, such as garbage tankage, may contain as little as 3 per cent of available plant food. When the products from these various sources are compounded into mixed fertilizer, the concentration of the mixture must always be less than that of the most concentrated material used in its preparation. Complete fertilizers containing as low as 10 per cent of total plant food constituents have been made, and for many years the average composition of the commercial mixed fertilizers could be represented by the analysis formula 2–8–2, i. e., 2 per cent NH_3, 8 per cent P_2O_5, and 2 per cent K_2O, by weight in the mixture.

If low-grade materials could be obtained in unlimited quantity near all points of consumption, there would perhaps be little economy in increasing their concentration. It is recognized that in the use of such materials there may be advantages which are lacking in the use of more concentrated materials: (1) A market is afforded for industrial by-products which would not have a market otherwise; (2) the fertilizing constituents in these materials may vary greatly in availability and thus serve to supply food to the plant throughout the growing season; (3) while many constituents of low-grade materials, such as sulphur and different forms of organic matter, add nothing to the commercial value of a fertilizer, they may nevertheless have a beneficial effect on many soils; (4) many low-grade materials have properties which improve the physical condition of the whole mixture; and (5), small amounts of plant food per acre can be applied more conveniently in the form of low-grade than very high-grade materials. It happens, however, that the use of fertilizers is now increasing most rapidly in those States that have a limited supply of many fertilizer materials, and the cost of handling and transporting low-grade fertilizers is a very serious disadvantage to their use in such localities.

This disadvantage has long been recognized, and considerable advance has already been made in increasing the concentration of many materials which require shipment to a distance. Commercial Chilean caliche, containing as low as 15 per cent sodium nitrate, is refined before shipment to a product analyzing 90 to 95 per cent sodium nitrate. Some of the German potash salts shipped to this country have been concentrated from about 9 per cent to 60 per cent potash, while a large proportion of the western potash salts produced since the war have been refined from a relatively low-grade material to one containing as high as 62 per cent potash. By the proper selection of these and other materials, the average analysis of mixed fertilizers has undergone a gradual increase in the last 10 years, amounting to about 30 per cent.

It is generally admitted, however, that fertilizers of still higher concentration are desirable, and there is now an active campaign to raise the analyses of mixed fertilizers, and to limit the number of analysis formulae. Action along these lines was taken at five conferences recently held at Chicago, Boston, Baltimore, Shreveport, and Atlanta, attended by agronomists of various States and representatives of manufacturers selling fertilizers in the States mentioned on p. 12. At these conferences, 52 analysis formulae[4] were recommended, varying from 14 to 32 per cent in plant food constituents, with an average of 18 per cent. These recommendations, if put into practice, would increase the concentration of fertilizers about 51 per cent over the average mixed fertilizer of a few years ago.

In addition to the cost of handling and transporting, there still remains a more serious objection to dependence on low-grade material for future expansion in fertilizer manufacture. This is the question of supply. A number of materials, as cottonseed meal, tankage, etc., which have been used extensively in fertilizers, are being used more and more as feed for livestock. The output of these industrial by-products is limited by the production of the principal products and can not be increased independently of the latter to meet an increased demand for the by-product.

To meet the probable future needs for nitrogenous materials, attention is now being directed to a source that is neither mineral deposit nor industrial by-product—namely, the nitrogen of the air.

When atmospheric nitrogen is fixed as ammonia, nitrogen is obtained in one of its most concentrated combinations. Ammonia, as such, however, can not be used directly as a commerical fertilizer; it becomes suited for this purpose only when neutralized with an acid.

Investigations by the Bureau of Soils,[5] now commercially utilized, have shown the feasibility of the industrial production of phosphoric acid by volatilization from phosphate rock, and the probable direct competition of this procedure with the sulphuric acid method for the treatment of phosphate rock. From the fertilizer standpoint, the newer method has the advantage of directly yielding an acid of a concentration most suitable for combining with ammonia, and for making, by substitution for sulphuric acid, many other concentrated materials such as the phosphates of sodium and potassium.

The manufacture of fixed nitrogen and of phosphoric acid thus provides the means for making many high-analysis fertilizer materials which may have wide application in the future if the supply of low-grade material falls short of the demand.

CONCENTRATED FERTILIZER COMPOUNDS

In Table 3 are given the chemical and physical properties of a number of inorganic materials which contain one or more of the essential constituents of fertilizers. The incompleteness of the table is due to the fragmentary nature of the data recorded in the literature, which, in addition, are often very conflicting. Some of the materials listed are now widely used in fertilizers. The data for the others are supplied for the purpose of showing which materials may have future application in increasing the concentration of fertilizers and which have properties that prevent their use for this purpose unless a satisfactory way is found to eliminate the properties that are considered objectionable.

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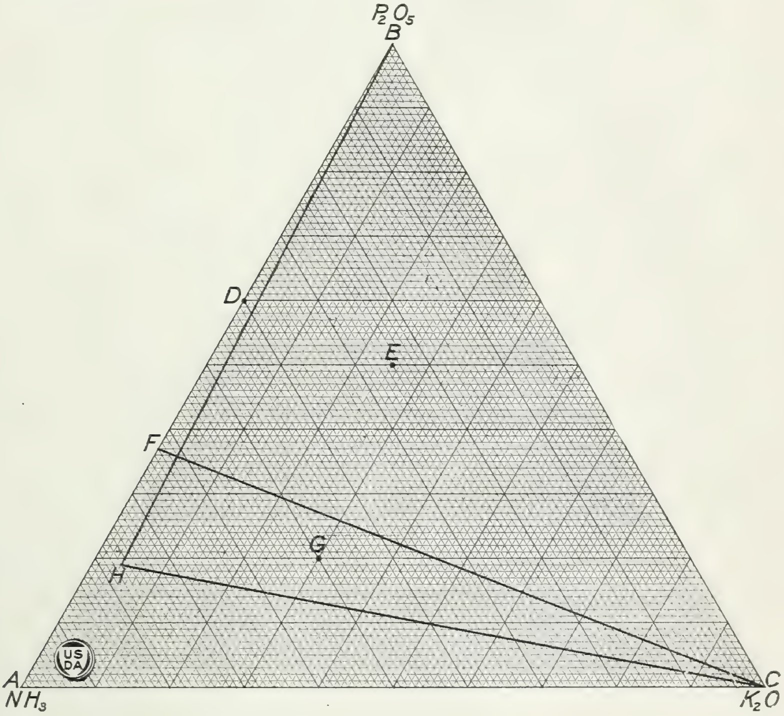
[4] The Standard Analyses. Anon. Am. Fertilizer, vol. 58, No. 4, p. 27, 1923; High Analysis. Anon. Am. Fertilizer, vol. 59, No. 9, p. 28, 1923.

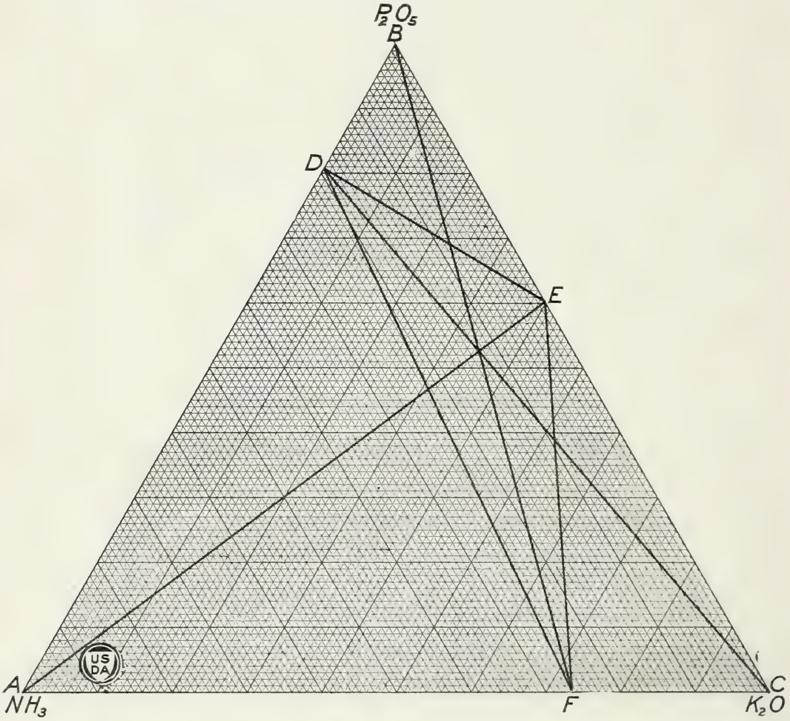
[5] The Use of the Cottrell Precipitator in Recovering the Phosphoric Acid Evolved in the Volatilization Method of Treating Phosphate Rock. W. H. Ross, J. N. Carothers, and A. R. Merz. J. Ind. Chem., vol. 9, p. 26–31, 1917; Electric Furnace Smelting of Phosphate Rock and Use of the Cottrell Precipitator in Collecting the Volatilized Phosphoric Acid. J. N. Carothers, J. Ind. Eng. Chem., vol. 10, p. 35–8, 1918; Investigations of the Manufacture of Phosphoric Acid by the Volatilization Process. W. H. Waggaman, H. W. Easterwood, and T. B. Turley. U. S. D. A. Dept. Bull. 1179, p.1–53, 1923.

TABLE 3.—*Properties of inorganic materials containing plant food constituents*

Material	Plant food constituents			Melting point	Decomposition temperature	Solubility in 100 parts of water	Density	Hygroscopicity	Chemical reaction	Undesirable properties for use in fertilizers	Extent of present use in fertilizers
	NH_3	P_2O_5	K_2O								
	Per ct.	*Per ct.*	*Per ct.*	*Degree C.*	*Degree C.*						
Ammonium bicarbonate	21.5				30-60	$27.0^{20°}$	1.59	Not hydroscopic	Slightly alkaline	Instability and incompatibility.	None.
Ammonium carbonate (commercial).	32.5			(1)		$25.0^{15°}$		do	Alkaline	do	Slight.
Ammonium chloride	31.8			(1)		$37.2^{20°}$	1.51	do	Neutral	None	Do.
Ammonium sulphate	25.8			140	280	$75.4^{20°}$	1.77	do	do	do	Very extensive.
Ammonium nitrate	42.5			154	185	$185^{20°}$	1.72	Hygroscopic	do	do	Slight.
Calcium nitrate	20.8			499		$56.4^{20°}$	2.40	do	do	Hygroscopicity	Moderate.
Calcium nitrate $Ca(NO_3)_2 4H_2O$	14.3			43		$134^{0°}$	1.85	do	do	do	None.
Sodium nitrate	20.0			313		$87.5^{20°}$	2.19	Slightly hygroscopic	do	do	Very extensive.
Monocalcium phosphate $Ca(H_2PO_4)_2. H_2O$.		56.3			100	(2)	2.02	Hygroscopic	Slightly acid	do	Do.
Dicalcium phosphate		52.2				$0.136^{25°}$		Not hygroscopic	Neutral	None	Moderate.
Dicalcium phosphate $CaHPO_4. 2H_2O$.		41.3			100	$0.01^{24°}$	2.32	do	do	do	Do.
Tricalcium phosphate		45.8			1,550	$0.002^{20°}$	3.18	Not hygroscopic	do	Insolubility	Do.
Monosodium phosphate		59.2			190	$84.6^{18°}$		do	Slightly acid	None	None.
Monosodium phosphate $NaH_2PO_4. H_2O$		51.5			100		2.05	do	do	do	Do.
Monosodium phosphate $NaH_2PO_4. 2H_2O$.		45.5		60		$110.8^{20°}$	1.95	do	do	do	Do.
Monosodium phosphate, acid $NaH_2PO_4. H_3PO_4$.		65.1		131				Very hygroscopic	Acid	Acidity and hydroscopicity.	Do.
Disodium pyrophosphate		64.0			204		1.86	Not hygroscopic	Neutral	None	Do.
Disodium pyrophosphate $Na_2H_2P_4O_7. 4H_2O$.		48.3						Effloresces	do	do	Do.
Tetrasodium pyrophosphate		53.4		880		$6.23^{20°}$	2.45	Not hygroscopic	Alkaline	Incompatibility	Do.
Tetrasodium pyrophosphate $Na_4P_2O_7. 10H_2O$.		31.8				$10.92^{20°}$	1.84	do	do	do	Do.
Disodium phosphate $Na_2HPO_4. 12H_2O$.		19.8		35	100	$17.2^{20°}$	1.53	Effloresces	Slightly alkaline	Low m. p	Do.
Trisodium phosphate		43.3					2.51		Alkaline	Incompatibiilty	Do.
Trisodium phosphate $Na_3PO_4. 7H_2O$.		24.5							do	do	Do.
Trisodium phosphate $Na_3PO_4. 12H_2O$.		18.3		75	100	$28.3^{15°}$	1.63		do	do	Do.
Potassium bicarbonate			47.0		110	$26.9^{20°}$	2.16	Not hygroscopic	Slightly alkal[illegible]	do	Do.
Potassium carbonate			68.2	890		$112.0^{20°}$	2.26	Hygroscopic	Alkaline	do	Moderate.



Triangular diagram illustrating the graphical representation of fertilizer ratios, and the ratios obtainable from fertilizer materials of given composition



Triangular diagram showing fertilizer ratios obtainable from combinations of monoammonium phosphate, monopotassium phosphate, and potassium nitrate, as well as those obtainable from combinations of these compounds with single fertilizer constituent materials

Potassium carbonate 2K$_2$CO$_3$.3H$_2$O.			57.0	900	100	89.4$^{0°}$	2.04	do	do	do	Slight.
Potassium chloride			63.2	782		34.0$^{20°}$	1.99	Not hygroscopic	Neutral	None	Very extensive.
Potassium bisulphate			34.6	197	200	51.4$^{20°}$	2.27	do	Acid	Acidity and incompatibility.	None.
Potassium sulphate			54.1	1,054		11.1$^{20°}$	2.66	do	Neutral	None	Very extensive.
Monoammonium phosphate	14.8	61.7				171$^{0°}$	1.79	do	Slightly acid	do	Slight.
Diammonium phosphate	25.8	53.8		(3)	(3)	131$^{15°}$	1.65	do	Slightly alkaline	Instability	None.
Triammonium phosphate (NH$_4$)$_3$PO$_4$.3H$_2$O.	25.1	35.0		(4)	(4)			do	Alkaline	do	Do.
Sodiumammonium phosphate NaNH$_4$HPO$_4$.4H$_2$O.	8.1	34.0		(2)	(2)	20$^{0°}$	1.55	do	Slightly alkaline	do	Do.
Potassium nitrate	16.9		46.6	339		31.2$^{20°}$	2.10	do	Neutral	None	Moderate.
Monopotassium phosphate		52.2	34.6		400	25.0$^{7°}$	2.34	do	Slightly acid	do	Slight.
Dipotassium phosphate		40.8	54.1					Hygroscopic	Alkaline	Incompatibility and hygroscopicity.	None.
Tripotassium phosphate		33.5	66.5	1,340				Not hygroscopic	do	Incompatibility	Do.
Dipostassium pyrophosphate		55.9	37.0					Hygroscopic	Neutral	Hygroscopicity	Do.
Tetrapotassium pyrophosphate		43.0	57.0					do	Alkaline	Hygroscopicity and incompatibility.	Do.
Potassium metaphosphate		60.1	39.9					Not hygroscopic	Neutral	None	Do.

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[1] Sublimes. [2] Decomposes. [3] Unstable in moist air. [4] Unstable at room temperature.

Among the concentrated materials listed in Table 3 are the salts, monoammonium phosphate, monopotassium phosphate, and potassium nitrate. These compounds contain combinations of all three fertilizer constituents in groups of two, and all have chemical and physical properties which make them admirably suited for use in fertilizers. Potassium nitrate has long been used to a limited extent in fertilizers, and is obtained from Chilean nitrate and other sources. It may also be prepared by treating potassium chloride with nitric acid such as that produced in the fixation of nitrogen. Monoammonium phosphate is now being used to some extent in high-grade fertilizers, and may be prepared by neutralizing ammonia, such as obtained in the fixation of nitrogen, with phosphoric acid. The use of monopotassium phosphate in fertilizers has been limited to experimental tests only. It may be prepared from potassium chloride and phosphoric acid. The percentage composition of these salts is given in Table 4.

TABLE 4.—*Composition of concentrated fertilizer salts*

Salt	Composition on basis of—					
	Total material			Fertilizing elements present		
	NH_3	P_2O_5	K_2O	NH_3	P_2O_5	K_2O
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Monoammonium phosphate, $NH_4H_2PO_4$	14.80	61.72	----------	19.34	80.66	----------
Monopotassium phosphate, KH_2PO_4	----------	52.18	34.59	----------	60.14	39.86
Potassium nitrate, KNO_3	16.85	----------	46.58	26.57	----------	74.43

FERTILIZER MIXTURES FROM CONCENTRATED MATERIALS

Applying the triangular system to fertilizer mixtures from concentrated materials, it is seen from the percentage values given in Table 4 that monoammonium phosphate corresponds to the point *D* in the triangle of Plate II; monopotassium phosphate to the point *E* and potassium nitrate to the point *F*. These three materials may therefore be used to make submultiples of all fertilizer ratios falling within the triangle *DEF*. In the same way, triangles may be drawn corresponding to combinations of any two of these compounds with a nitrogen, phosphoric acid, or potash salt. Thus the triangle *ADE* incloses all possible ratios that can be made with mixtures of monoammonium phosphate, monopotassium phosphate, and a nitrogen compound; the triangle *CDE* all ratios that can be prepared from the same two compounds and a potash salt, and the triangle *BDE* all the ratios that can be made from these two compounds and a phosphatic material, such as acid phosphate.

When each of three materials selected for a mixture contains two fertilizing elements, then the amount of each required to give a ton of a fertilizer of any analysis formula which they are capable of making, as shown by the triangle method, may be calculated as follows:

If A, B, and C are the percentages respectively of the NH_3, P_2O_5, and K_2O desired in the mixed fertilizer, and—

X = Weight of material containing a per cent NH_3, and b per cent P_2O_5.

Y = Weight of material containing b' per cent P_2O_5, and c per cent K_2O.

Z = Weight of material containing c' per cent K_2O, and a' per cent NH_3.

$$\text{Then } X = 2000\ \frac{b'\ c'\ A + a'\ c\ B - a'\ b'\ C}{ab'\ c' + a'\ bc} \tag{1}$$

$$Y = \frac{2000\ B - bX}{b'}\text{, and} \tag{2}$$

$$Z = \frac{2000\ C - cY}{c'} \tag{3}$$

For the particular case where the three materials used are monoammonium phosphate, monopotassium phosphate, and potassium nitrate respectively,

$$\text{X, monoammonium phosphate} = 2000\ \frac{2430.54\,A + 582.84B - 879.23\,C}{71945}$$

$$\text{Y, monopotassium phosphate} = \frac{2000\ B - 61.72\,X}{52.18}$$

$$\text{Z, potassium nitrate} = \frac{2000\ C - 34.6\ Y}{46.58}$$

The number of fertilizer ratios it is possible to make from these materials is limited, as already explained, and the same is true of any three materials which contain two constituents each. However, by successively combining these materials in pairs with ammonia, phosphoric acid, and potash salts, nine possible combinations are obtained and can be used, by varying the materials in any combination, to make any fertilizer ratio whatever. In Table 5 are given expressions for calculating for each of these nine combinations the quantities of the materials required for any fertilizer formula falling within the triangle representing the combination in Plate II.

TABLE 5.—*Expressions for calculating the quantities of material required for a ton of an A–B–C fertilizer when materials that contain two fertilizing elements are combined in pairs with an NH_3, P_2O_5, or K_2O salt*

Mixture of—	X	Y	Z	M_{NH_3}	M_{K_2O}	$M_{P_2O_5}$
$X+Y+M_{K_2O}$	$\frac{2{,}000\ A}{a}$	$\frac{2{,}000\ B-bX}{b'}$	----------	----------	$\frac{2{,}000\ C-cY}{c''}$	
$X+Y+M_{NH_3}$	$\frac{2{,}000\ B-b'Y}{b}$	$\frac{2{,}000\ C}{c}$	----------	$\frac{2{,}000\ A-aX}{a''}$	----------	
$X+Y+M_{P_2O}$	$\frac{2{,}000\ A}{a}$	$\frac{2{,}000\ C}{c}$	----------	----------	----------	$\frac{2{,}000\ B-bX-b'Y}{b''}$
$Y+Z+M_{NH_3}$	----------	$\frac{2{,}000\ B}{b'}$	$\frac{2{,}000\ C-cY}{c'}$	$\frac{2{,}000\ A-a'Z}{a''}$	----------	
$Y+Z+M_{P_2O_5}$	----------	$\frac{2{,}000\ C-c'Z}{c}$	$\frac{2{,}000\ A}{a'}$	----------	----------	$\frac{2{,}000\ B-b'Y}{b''}$
$Y+Z+M_{K_2O}$	----------	$\frac{2{,}000\ B}{b'}$	$\frac{2{,}000\ A}{a'}$	----------	$\frac{2{,}000\ C-cY-c'Z}{c''}$	
$Z+X+M_{K_2O}$	$\frac{2{,}000\ B}{b}$	----------	$\frac{2{,}000\ A-aX}{a'}$	----------	$\frac{2{,}000\ C-c'Z}{c''}$	
$Z+X+M_{NH_3}$	$\frac{2{,}000\ B}{b}$	----------	$\frac{2{,}000\ C}{c'}$	$\frac{2{,}000\ A-a'Z-aX}{a''}$	----------	
$Z+X+M_{P_2O_5}$	$\frac{2{,}000\ A-a'Z}{a}$	----------	$\frac{2{,}000\ C}{c'}$	----------	----------	$\frac{2{,}000\ B-bX}{b''}$

X, quantity of material containing a per cent NH_3 and b per cent P_2O_5.
Y, quantity of material containing b' per cent P_2O_5 and c per cent K_2O.
Z, quantity of material containing c' per cent K_2O and a' per cent NH_3.
M_{NH_3}, quantity of material containing a'' per cent NH_3.
$M_{P_2O_5}$, quantity of material containing b'' per cent P_2O_5.
M_{K_2O}, quantity of material containing c'' per cent K_2O.

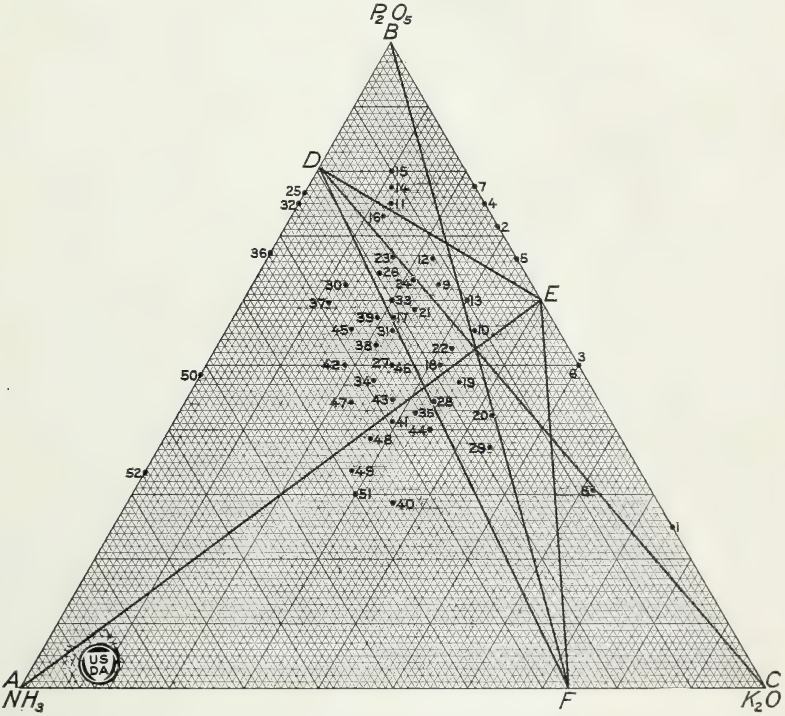
STANDARD FERTILIZER MIXTURES FROM CONCENTRATED MATERIALS

In Table 6 are listed the different fertilizer analysis formulae recommended by the five agricultural conferences already referred to for adoption. The States represented at these different conferences were: (A) Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut; (B) New York, Pennsylvania, New Jersey, Delaware, Maryland, Virginia, and West Virginia; (C) Ohio, Missouri, Michigan, Indiana, and Wisconsin; (D) Arkansas, Texas, and Louisiana; (E) North Carolina, South Carolina, and Georgia.

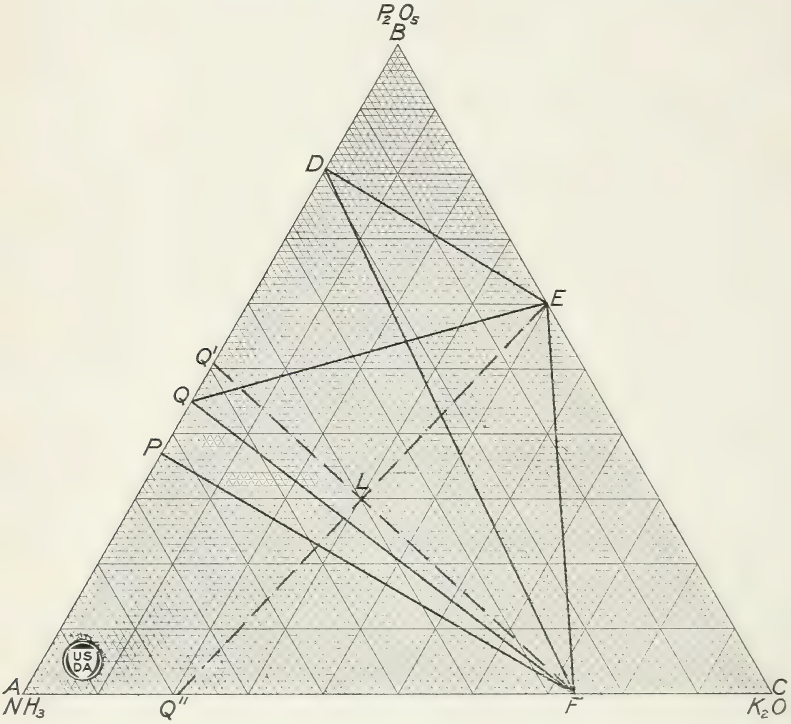
TABLE 6.—*Fertilizer-analysis formulae recommended by five regional agricultural conferences for adoption*

A	B	C	D	E	A	B	C	D	E
		0–8–24			4–8–4	4–8–4			4–8–4
	0–10–4				4–8–6	4–8–6	4–8–6		4–8–6
	0–10–10	0–10–10				4–8–10			
			0–12–4	0–12–4					4–10–2
0–12–6	0–12–6	0–12–6							4–10–4
		0–12–12				4–12–0	4–12–0		4–12–0
		0–14–4				4–12–4			4–12–4
		2–8–16						4.86–8–4	
				2–10–4				4.86–8–6	
	2–10–6							4.86–10–0	
	2–12–2	2–12–2						4.86–10–2	
2–12–4	2–12–4	2–12–4						4.86–10–4	
		2–12–6						4.86–12–4	
		2–14–2			5–4–5				
		2–16–2							5–7–5
			2.43–12–2						5–8–3
	3–8–3					5–8–5			
				3–8–5	5–8–7				
		3–8–6							5–10–3
	3–8–8					5–10–5			
3–10–4						6–8–4			
3–10–6	3–10–6							6.07–7–5	
				3–12–3		7–6–5			7–6–5
		3–12–4			8–6–6				
			3.64–12–0					8.5–8–0	
			3.64–12–3			10–5–0			

The ratios corresponding to each of these analysis formulae are plotted as points in the triangle of Plate III. By plotting also the lines, or triangles corresponding to any desired materials combined in groups of two or three, it may be seen at a glance what analysis formula can be made from any given materials. Thus 17 of the 52 standard analysis formulae plotted in Plate III fall within the triangle *DEF* and may, therefore, be prepared from combinations of monoammonium phosphate, monopotassium phosphate, and potassium nitrate. Nineteen other analysis formulae fall within the triangle *ADF* and may be prepared from combinations of monoammonium phosphate, potassium nitrate, and an ammonium salt. The location of the remaining 16 analysis formulae shows in a similar way what materials may be taken for their preparation. Of these 16 formulae 12 contain but two fertilizing elements. It may be noted also that a number of the analysis formulae fall within several triangles, indicating that they may be made by different combinations. Thus the analysis formula 3–10–6, numbered 22 in Plate III, falls within the four triangles *DEF*, *ADE*, *DFB*, and *DFC*, and may be prepared from monoammonium phosphate and monopotassium phosphate in combination with (1) an ammonium salt or (2) potassium nitrate; or from monoammonium phosphate and potassium nitrate in combination with (3) a phosphoric-acid salt or (4) potash salt.



Showing the location of the fertilizer ratios of 52 standard high-analysis fertilizers on the diagram of Plate II



Triangular diagram showing the fertilizer ratios obtainable from combinations of monoammonium phosphate, monopotassium phosphate, and potassium nitrate with a fourth fertilizer material

The quantities of these or any other materials required in the preparation of this or any other analysis formula may be calculated by means of the expressions given above.

In Table 7, by way of illustration, are given the weights of monoammonium phosphate, monopotassium phosphate, and potassium nitrate required for a ton of mixed fertilizer when combined together or taken in pairs with an ammonium, phosphoric-acid, or potash salt for the preparation of the standard fertilizer analysis formulae listed above. The weights of the materials given in the table have been calculated on the basis of 100 per cent purity. In the case of the commercial preparation of fertilizer mixtures, it will be necessary to divide the weights given in the table by the percentage of purity of the fertilizer material, and multiply by 100, to determine what quantity of the commercial material to use.

TABLE 7.—*Weights of materials which may be used in making a ton of standard fertilizers*

Number	Analysis formula	Ratio	$NH_4H_2PO_4$	KH_2PO_4	KNO_3	Fertilizer constituents supplied by other materials		
						NH_3	K_2O	P_2O_5
				Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
1	0-8-24	0-25-75		306. 6			374. 0	
2	0-10-4	0-71. 43-28. 57		231. 3				79. 3
3	0-10-10	0-50-50		383. 3			67. 4	
4	0-12-4	0-75-25		231. 3				119. 3
5	0-12-6	0-66. 67-33. 33		346. 9				59. 0
6	0-12-12	0-50-50		459. 9			80. 9	
7	0-14-4	0-77. 78-22. 22		231. 3				159. 3
8	2-8-16	7. 69-30. 77-61. 54	259. 2		9. 5		315. 6	
8	2-8-16	7. 69-30. 77-61. 54		306. 6	237. 4		103. 4	
9	2-10-4	12. 5-62. 5-25	199. 4	147. 4	62. 3			
9	2-10-4	12. 5-62. 5-25	128. 5	231. 3		21. 0		
9	2-10-4	12. 5-62. 5-25	270. 3	63. 6			58. 0	
9	2-10-4	12. 5-62. 5-25	75. 0		171. 7			153. 7
10	2-10-6	11. 11-55. 56-33. 33	150. 5	205. 3	105. 2			
10	2-10-6	11. 11-55. 56-33. 33	30. 8	346. 9		35. 5		
10	2-10—6	11. 11-55. 56-33. 33		27. 5	237. 3			185. 7
10	2-10-6	11. 11-55. 56-33. 33	270. 3	63. 6			98. 1	
11	2-12-2	12. 5-75-12. 5	270. 3	115. 7				12. 9
11	2-12-2	12. 5-75-12. 5	172. 3		85. 9			133. 7
12	2-12-4	11. 11-66. 67-22. 22	231. 8	185. 7	33. 9			
12	2-12-4	11. 11-66. 67-22. 22	193. 3	231. 3		11. 4		
12	2-12-4	11. 11-66. 67-22. 22	75. 0		171. 7			193. 7
12	2-12-4	11. 11-66. 67-22. 22	270. 3	140. 3			31. 5	
13	2-12-6	10-60-30	182. 9	243. 7	76. 7			
13	2-12-6	10-60-30		27. 2	237. 4			225. 8
13	2-12-6	10-60-30	95. 6	346. 9		25. 9		
13	2-12-6	10-60-30	270. 3	140. 3			71. 5	
14	2-14-2	11. 11-77. 78-11. 11	270. 3	115. 7				52. 9
14	2-14-2	11. 11-77. 78-11. 11	172. 3		85. 9			173. 7
15	2-16-2	10-80-10	270. 3	115. 7				92. 9
15	2-16-2	10-80-10	172. 3		85. 9			213. 7
16	2. 43-12-2	14. 79-73. 04-12. 17	309. 7	93. 6	16. 4			
16	2. 43-12-2	14. 79-73. 04-12. 17	291. 1	115. 6		5. 5		
16	2. 43-12-2	14. 79-73. 04-12. 17	328. 4	71. 5			15. 3	
16	2. 43-12-2	14. 79-73. 04-12. 17	230. 4		85. 9			97. 8
17	3-8-3	21. 42-57. 14-21. 43	259. 0	. 3	128. 6			
17	3-8-3	21. 42-57. 14-21. 43	112. 6	173. 5		43. 4		
17	3-8-3	21. 42-57. 14-21. 43	258. 9		128. 8			. 3
17	3-8-3	21. 42-57. 14-21. 43	259. 3		128. 8			
18	3-8-5	18. 75-50-31. 25	210. 1	58. 1	171. 5			
18	3-8-5	18. 75-50-31. 25	14. 7	289. 1		57. 8		
18	3-8-5	18. 75-50-31. 25	259. 2		128. 2		40. 3	
18	3-8-5	18. 75-50-31. 25	160. 8		214. 7			60. 8
19	3-8-6	17. 65-47. 06-35. 29	185. 7	87. 0	193. 0			
19	3-8-6	17. 65-47. 06-35. 29	112. 2		257. 6			90. 8
19	3-8-6	17. 65-47. 06-35. 29	259. 3		128. 2		60. 3	
19	3-8-6	17. 65-47. 06-35. 29		306. 6	29. 8	55. 0		
20	3-8-8	15. 78-42. 11-42. 11	136. 8	144. 8	236. 0			
20	2-8-8	15. 78-42. 11-42. 11	14. 2		343. 5			151. 2
20	3-8-8	15. 78-42. 11-42. 11	259. 3		128. 2		100. 3	
20	3-8-8	15. 78-42. 11-42. 11		306. 6	115. 7	40. 5		
21	3-10-4	17. 65-58. 82-23. 53	267. 0	67. 5	121. 6			

TABLE 7.—*Weights of materials which may be used in making a ton of standard fertilizers*—Continued

Number	Analysis formula	Ratio	$NH_4H_2PO_4$	KH_2PO_4	KNO_3	Fertilizer constituents supplied by other materials		
						NH_3	K_2O	P_2O_5
				Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
21	3-10-4	17.65-58.82-23.53	128.5	231.3		41.0		
21	3-10-4	17.65-58.82-23.53	210.1		171.7			70.4
21	3-10-4	17.65-58.82-23.53	324.1		71.8		46.6	
22	3-10-6	15.79-52.63-31.58	218.1	125.3	164.6			
22	3-10-6	15.79-52.63-31.58	30.8	346.9		55.4		
22	3-10-6	15.79-52.63-31.58	112.2		257.6			130.8
22	3-10-6	15.79-52.63-31.58	324.0		71.2		86.8	
23	3-12-3	16.67-66.67-16.66	323.8	76.9	71.7			
23	3-12-3	16.67-66.67-16.66	258.8		128.8			80.3
23	3-12-3	16.67-66.67-16.66	242.2	173.5		24.2		
23	3-12-3	16.67-66.67-16.66	388.9		14.2		53.4	
24	3-12-4	15.79-63.16-21.05	299.3	105.9	93.1			
24	3-12-4	15.79-63.16-21.05	193.3	231.3		31.4		
24	3-12-4	15.79-63.16-21.05	210.1		171.7			110.4
24	3-12-4	15.79-63.16-21.05	388.9		14.2		73.4	
25	3.64-12-0	23.27-76.73-0	388.9			15.3		
26	3.64-12-3	19.53-64.38-16.09	367.0	25.8	109.7			
26	3.64-12-3	19.53-64.38-16.09	242.2	173.5		37.0		
26	3.64-12-3	19.53-64.38-16.09	345.3		128.8			26.9
26	3.64-12-3	19.53-64.38-16.09	388.9		90.2		18.0	
27	4-8-4	25-50-25	63.7	231.3		70.6		
27	4-8-4	25-50-25	259.3		171.7	12.7		
28	4-8-6	22.22-44.45-33.33	253.2	7.1	252.3			
28	4-8-6	22.22-44.45-33.33	247.3		257.6			7.4
28	4-8-6	22.22-44.45-33.33	259.2		246.9		5.0	
28	4-8-6	22.22-44.45-33.33		306.6	29.8	75.0		
29	4-8-10	18.18-36.37-45.45	155.5	122.7	338.3			
29	4-8-10	18.18-36.37-45.45	51.4		429.4			128.3
29	4-8-10	18.18-36.37-45.45	259.2		246.9		85.0	
29	4-8-10	18.18-36.37-45.45		306.6	201.6	46.0		
30	4-10-2	25-62.5-12.5	226.3	115.6		46.6		
30	4-10-2	25-62.5-12.5	324.0		85.9	17.5		
31	4-10-4	22.22-55.56-22.22	128.5	231.3		61.0		
31	4-10-4	22.22-55.56-22.22	324.0		171.7	3.1		
32	4-12-0	25-75-0	388.9			22.5		
33	4-12-4	20-60-20	366.9	26.0	152.4			
33	4-12-4	20-60-20	193.3	231.3			51.4	
33	4-12-4	20-60-20	345.3		171.7			26.9
33	4-12-4	20-60-20	388.9		132.9		18.1	
34	4.86-8-4	28.83-47.45-23.72	63.7	231.3		87.8		
34	4.86-8-4	28.83-47.45-23.72	259.3		171.7	29.9		
35	4.86-8-6	25.77-42.42-31.81	259.2		257.6	15.4		
35	4.86-8-6	25.77-42.42-31.81		306.6	29.8	92.2		
36	4.86-10-0	32.71-67.29-0	324.0			49.3		
37	4.86-10-2	28.83-59.31-11.86	226.3	115.6		63.8		
37	4.86-10-2	28.83-59.31-11.86	324.0		85.9	34.8		
38	4.86-10-4	25.77-53.02-21.21	128.5	231.3		78.2		
38	4.86-10-4	25.77-53.02-21.21	324.0		171.7	20.4		
39	4.86-12-4	23.30-57.52-19.18	193.3	231.3		68.6		
39	4.86-12-4	23.30-57.52-19.18	388.9		171.7	10.7		
40	5-4-5	35.71-28.57-35.72		153.3	100.9	83.0		
40	5-4-5	35.71-28.57-35.72	129.6		214.7	44.6		
41	5-7-5	29.41-41.18-29.41	226.8		214.7	30.2		
41	5-7-5	29.41-41.18-29.41		268.3	15.5	97.4		
42	5-8-3	31.25-50-18.75	112.6	173.5		83.3		
42	5-8-3	31.25-50-18.75	259.3		128.8	39.9		
43	5-8-5	27.78-44.44-27.78	14.9	289.1		97.8		
43	5-8-5	27.78-44.44-27.78	259.2		214.7	25.4		
44	5-8-7	25-40-35		306.6	73.0	87.7		
44	5-8-7	25-40-35	259.3		300.6	10.9		
45	5-10-3	27.78-55.55-16.67	177.4	173.5		73.7		
45	5-10-3	27.78-55.55-16.67	324.0		128.8	30.3		
46	5-10-5	25-50-25	79.7	289.1		88.2		
46	5-10-5	25-50-25	324.0		214.6	15.9		
47	6-8-4	33.33-44.45-22.22	63.8	231.3		110.6		
47	6-8-4	33.33-44.45-22.22	259.2		171.7	52.7		
48	6.07-7-5	33.59-38.74-27.67	226.8		214.7	51.6		
48	6.07-7-5	33.59-38.74-27.67		268.3	15.5	118.8		
49	7-6-5	38.89-33.33-27.78		230.0	44.0	132.6		
49	7-6-5	38.89-33.33-27.78	194.4		214.7	75.0		
50	8.5-8-0	51.52-48.48-0	259.2			131.6		
51	8-6-6	40-30-30		230.0	86.9	145.4		
51	8-6-6	40-30-30	194.4		257.6	87.8		
52	10-5-0	66.67-33.33-0	162.0			176.1		

If it is desired to combine a fourth material in a mixture with three others containing two fertilizing elements each, such as monoammonium phosphate, monopotassium phosphate, and potassium nitrate, two special cases may be considered, depending on whether the fourth material contains one, or two, fertilizer constituents.

A nitrogen compound such as ammonium nitrate is represented in the triangle of Plate IV by the point *A*. By plotting the points *D*, *E*, and *F* as before to represent the ammonium and potassium phosphates and potassium nitrate, the area *ADEF* will inclose all possible fertilizer ratios that can be prepared from mixtures of these materials.

If the fourth material has a composition similar to tankage (containing 8.5 per cent of NH_3, and 5 per cent of P_2O_5), it may be represented in the figure by the point *P*, and only fertilizer ratios falling within the area *PDEF* can be made from these four materials.

In calculating the quantities of the four materials required for a ton of any given analysis formula, such as the 8–6–6 mixture represented at the point *L*, the two NH_3–P_2O_5 materials may be taken arbitrarily in any proportion such that the point *Q* representing the mixture will form the apex of a triangle on the base *EF* inclosing *L*. It is apparent from the figure that the location of the point *Q* may vary from *P* (representing the tankage alone) to the point *Q'*, which becomes the apex of the triangle when the side *FQ'* passes through *L*. The relative quantities of the two materials required to form a mixture containing a given ratio (r) of NH_3: P_2O_5 corresponding to *Q* is determined as follows:

Let x = quantity of the first material.
y = quantity of the second material.
a = percentage of NH_3 in first material.
a'' = percentage of NH_3 in second material.
b = percentage of P_2O_5 in first material.
b'' = percentage of P_2O_5 in second material.

$$\text{Then, } \frac{ax+a''y}{bx+b''y}=r$$

or

$$y=\frac{a-rb}{rb''-a''}x$$

For monoammonium phosphate and tankage,

$a=14.8$; $a''=8.5$; $b=61.72$; and $b''=5$

For monoammonium phosphate and ammonium nitrate,

$a=14.8$; $a''=42.55$; $b=61.72$; and $b''=0$

If a ratio of NH_3: P_2O_5 in the mixture is selected corresponding to the point *Q*, which represents 55 parts of NH_3 to 45 of P_2O_5, $r=55/45$; whence for tankage with monoammonium phosphate, $y=25.4\ x$, and for ammonium nitrate with monoammonium phosphate, $y=1.43\ x$.

Mixtures corresponding to the point *Q* may therefore be prepared from 25.4 pounds of tankage, or 1.43 pounds of ammonium nitrate, with one of monoammonium phosphate.

The quantities of these materials, together with monopotassium phosphate and potassium nitrate, required for a ton of an 8–6–6 fertilizer may then be calculated by help of equations (1), (2), and (3), with results as follows:

	Case 1 (pounds)	Case 2 (pounds)
Monoammonium phosphate	160. 7	52. 7
Monopotassium phosphate	39. 8	39. 5
Potassium nitrate	228. 0	228. 3
Ammonium nitrate	229. 9	-------
Tankage	-----	1, 337. 7

In a similar way, calculations may be made of fertilizer mixtures using four materials of other composition, or any additional number of fertilizer compounds.

SUMMARY

The materials now used in the fertilizer industry contain, as a rule, only one of the three plant-food constituents. Consequently, the calculation of the quantities of these materials required for a mixed fertilizer of given analysis formula is a comparatively easy arithmetical process.

As the number of materials, particularly of single constituent materials, available for a fertilizer mixture is reduced, the range of fertilizer analysis formulae which they are capable of making is also reduced, and the difficulty of the ordinary arithmetical method of calculating any mixture may be greatly increased.

It is pointed out that the number of materials used in mixed fertilizers is likely to decrease, and that the concentration of those used will probably increase.

A method is presented whereby it can be quickly ascertained, by means of triangular diagrams, whether a mixed fertilizer of given analysis formula can be made from combinations of two-fertilizer-constituent materials.

Formulae are given for the computation of the respective quantities of these materials required for making mixed fertilizers in those cases in which the fertilizer can be made from these materials.

Tables are presented giving the results of such computations for the 52 analysis formulae adopted by conferences of agronomists and fertilizer manufacturers as standard for the 24 States represented.

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